IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors:	James M. Holden, William A. McGahan, Richard A. Yarussi; Pablo I. Rovira; and Roger R. Lowe-Webb		
Assignee:	Nanometrics Incorporated		
Title:	Apparatus and Method for the Measurement of Diffracting Structures		
Serial No.:	09/670,000	Filing Date:	September 25, 2000
Examiner:	Chih-Cheng Glen Kao	Group Art Unit:	2882
Docket No.:	NAN022 US	Confirmation No:	3656

Santa Clara, California
June 16, 2004

Mail Stop Amendment
Commissioner For Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION PURSUANT TO 37 C.F.R. §1.131

Dear Sir:

This Declaration is offered to prove conception and diligent constructive reduction to practice of Claims 3-16, 27, and 28 in the above-identified application prior to September 20, 2000, the effective priority date of Wack et al., (6,673,637), (referred to herein as "Wack").

I, Michael J. Halbert, the attorney that prepared the present application, declare as follows:

1. I am currently a partner in the firm Silicon Valley Patent Group LLP, 2350 Mission College Boulevard, Santa Clara, California.

2. I was an associate at the firm Skjerven Morrill MacPherson LLP, 25 Metro Drive, San Jose, California (referred to herein as "Skjerven"), and was responsible for preparing the above-referenced application (the "Application"). The Application was prepared for Nanometrics Incorporated (referred to herein as "Nanometrics"), and was assigned attorney docket number "M-9455 US" by Skjerven.

3. Attached hereto as Exhibit A is a copy of an email cover page and the attached internal Nanometrics' invention disclosure entitled "Normal Incidence Spectroscopic

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Reflectometer with Analyzer for the Measurement of Diffracting Structures" prepared by James M. Holden, and transmitted to me by email on August 21, 2000. This disclosure was used by me in preparing the Application. Portions of Exhibit A that are immaterial to the conception of the invention have been deleted.

4. Exhibit B is a copy of the first page of an Itemized Service Bill that memorializes my activity in this case in August 2000. Irrelevant material, such as billing information, has been redacted from Exhibit B. As can be seen in Exhibit B, after receiving the disclosure, Mr. Holden and I had a phone conference to discuss the invention. I then began drafting the present application. This work is reflected in the Itemized Service Bill attached as Exhibit B.

5. On August 28, 2000, I finalized an initial draft of the Application and transmitted the draft via facsimile to Nanometrics for Mr. Holden's review. The transmittal of the draft Application is evidenced by the Itemized Service Bill of Exhibit B and a transmittal letter, a copy of which is in the Application's file and is attached hereto as Exhibit C.

6. It is my understanding that during the time period from Mr. Holden's receipt of the initial draft until about September 15, 2000, Mr. Holden and the other inventors were engaged in reviewing the initial draft of the Application.

7. Exhibit D is a copy of the first page of an Itemized Service Bill that memorializes my activity in this case in September 2000. Irrelevant material, such as billing information, has been redacted from Exhibit D. On or about September 15, 2000, I received additional disclosures from Mr. Holden and Mr. McGahan. After analyzing the additional disclosures and after a telephone conference with Mr. Holden and Mr. McGahan, I continued to prepare the application. This work is reflected in the Itemized Service Bill attached as Exhibit D.

8. On September 20, 2000, I received another set of comments from the inventors. Exhibit E is a copy of an email cover page and the first page and the fourth page of comments on a draft Application from Mr. Holden dated September 20, 2000. Portions of Exhibit E that are immaterial to the conception of the invention have been deleted. The hand written note on the top right corner of page 1 of the draft Application of Exhibit E was written

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by myself at the time of receipt. Page 4 of the draft Application shows that the rotatable analyzer/polarizer was included in the draft Application. As Mr. Holden is providing his comments to me on this draft Application on September 20, 2000, it is clear that the draft Application was transmitted by me to Mr. Holden before September 20, 2000.

9. On September 20, 2000, I revised the draft Application according to Mr. Holden's comments , and transmitted the draft Application to the inventors. This work is reflected in the Itemized Service Bill attached as Exhibit D.

10. From September 20, 2000 until the filing of the Application on September 25, 2000, I was in daily contact with the inventors to receive their comments and to provide revisions to the Application for the inventor's review. This work is reflected in the Itemized Service Bill attached as Exhibit D. It should be noted that September 23 and 24 fell on the weekend and that neither Nanometrics nor Skjerven had normal business hours on the weekend.

11. Thus, the conception date of the present invention as recited in Claims 3-16, 27, and 28 was prior to the effective priority date of Wack, September 20, 2000, as evidenced by the disclosures provided to me prior to that date, which is evidenced by Exhibit A, and the Itemized Service Bills of Exhibits B and D, as well as the portions of the Draft Application with Mr. Holden's comments dated September 20, 2000, shown in Exhibit E.

12. Moreover, as can be seen in the Itemized Service Bill of Exhibit D, there was daily activity and, accordingly, due diligence from September 20, 2000, the effective date of Wack, to the subsequent filing of the Application.

I assert that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Dated: June 16, 2004

Respectfully submitted,

Michael J. Halbert

Michael J. Halbert
Attorney for Applicants
Reg. No. 40,633

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Michael Halbert

From: Matt Holden [mholden@nanometrics.com]
Sent: Monday, August 21, 2000 2:28 PM
To: mhalbert@smmff.com

Normal Incidence Spectroscopic...

ATT02123.txt

EXHIBIT A

Normal Incidence Spectroscopic Reflectometer with Analyzer for the Measurement of Diffracting Structures

Detailed Description of Invention

Referring to Figure 1, unpolarized light is provided by UV-visible light source **1** and collected and collimated by lens **2**. A fraction of this collimated, broadband, unpolarized light beam is bent by beamsplitter **3**. The light is focused by objective **4** at near normal incidence with marginal rays **5** and **6** at small angles from the normal ray **10** on the diffraction grating structure **7** under study. Typically, the grating structure will be a small pad **7** on a patterned silicon wafer **8** residing on a movable wafer stage **9**. The wafer stage may be capable of any or all of x, y, z, and/or θ movement.

Referring to Figure 2, unpolarized light travelling in the direction **18** has roughly equal electric field components polarized perpendicular **20** (sometimes called TM) and parallel **21** (sometimes called TE) to the lines of a diffraction grating structure **19**. The reflected beam travelling in direction **22** has TM component **23** and TE component **24** with intensities modified by the polarizing diffraction structure.

Referring again to Figure 1, light reflected from the grating is re-collimated by lens **4** and a fraction passes through the beamsplitter **3**. The beam passes through a rotating or rotatable analyzer **11**. The analyzer passes only the electric field component of the reflected beam that is coincident with the polarization axis of the analyzer. The beam is linearly polarized after passing through the analyzer. This beam is focused by lens **12** to the entrance slit of a spectrograph **13**. The spectrograph disperses the full spectrum into spectral components across an array of detector pixels. Each pixel corresponds to a different wavelength, thus the spectrograph generates a spectrograph signal, $S(\lambda)$, as a function of wavelength λ. Typically, $S(\lambda)$ is corrected as well as possible for electronic background and internal reflections.

For sample viewing and alignment, a visible lamp **15** provides flood illumination via movable mirror **16**. This flood illumination is reflected off mirror **14** to a camera and pattern recognition system **17**. The pattern recognition system can provide a measure of grating orientation relative to the analyzer.

A reflectometer without movable optics in the beam path is generally calibrated by measuring the spectrograph signal $S_o(\lambda)$ from a sample with well-known reflectance, $R_o(\lambda)$ such as bare silicon with a native oxide. This signal is compared to the

spectrograph signal from the sample under study, $S(\lambda)$. The absolute reflectance, $R(\lambda)$, is then calculated as

$$R(\lambda) = g(\lambda)\frac{S(\lambda)}{S_o(\lambda)}R_o(\lambda)$$

with the understanding that the optical system does not change substantially between the time when $S(\lambda)$ is measured and the time when $S_o(\lambda)$ is measured. In practice, this calibration need only be done once or occasionally. Time variations in source intensity are removed by applying a wavelength dependent multiplier $g(\lambda)$.

The present invention has a rotatable analyzer and components such as beamsplitter **3** and spectrograph **13** that have polarization dependent efficiencies. Therefore the calibration above must be repeated for all orientations of the analyzer, Θ, measured relative to some arbitrary machine fiducial. The calibration now produces the function $S_o(\lambda,\Theta)$. In practice, this would be done at a discrete set of equally spaced angles on a uniform, non-polarizing (at normal incidence) surface such as bare silicon with a native oxide. $S_o(\lambda,\Theta)$ for an angle between two of the equally spaced angles would be calculated by some suitable interpolation scheme on a λ by λ basis. The reflectance is then calculated as

$$R(\lambda) = g(\lambda)\frac{S(\lambda,\Theta_o)}{S_o(\lambda,\Theta_o)}R_o(\lambda)$$

where Θ_o is the analyzer orientation at the time of measurement and $S(\lambda,\Theta_o)$ is the sample spectrograph signal.

There are two analyzer angles, Θ_{TE} and $\Theta_{TE}+\pi$ when the analyzer will pass only the TE component and two analyzer angles, $\Theta_{TE}\pm\pi/2$ when only the TM component will pass through the analyzer. Because the electric field of the reflected beam can be written as a superposition of TE and TM components relative to the diffraction grating, $R(\lambda)$ will have sinusoidal variation with Θ, reaching extrema at Θ_{TE}, $\Theta_{TE}+\pi/2$, $\Theta_{TE}+\pi$, and $\Theta_{TE}-\pi/2$. The absolute reflectances for TE and TM components are labeled $R_{TE}(\lambda)$ and $R_{TM}(\lambda)$, respectively. Whether a particular extrema corresponds to TE or TM light can be determined from the observation that $R_{TM}(\lambda)$ is generally less than $R_{TE}(\lambda)$ and/or knowledge of the sample orientation and the pattern recognition system.

Actual measurements can be made in either an absolute fashion where the analyzer is driven to the TM and TE positions or in a relative fashion where the analyzer is rotated continuously and we are interested in the ratio of $R_{TE}(\lambda)$ to $R_{TM}(\lambda)$.

An important aspect of this invention is that because of the rotating element and operation at normal incidence, the orientation of the grating structure does not affect the accuracy of the measurement. The optics are always aligned to the structure. This is of particular advantage when coupled with an r-θ sample stage.

The reflectances $R_{TE}(\lambda)$ and $R_{TM}(\lambda)$ from the polarizing diffraction grating can be used to deduce information about the grating such as pitch, linewidth, and lineshape via exact modeling of reflectance after an analysis technique and body of work begun by M. G. Moharam and T. K. Gaylord. The analysis method is called RCWA and is exemplified by M. G. Moharam and T. K. Gaylord, "Rigorous coupled-wave analysis of planar grating diffraction", J. Opt. Soc. Am., vol. 71, no. 7, pp811-818, (1983) and subsequent publications by the same and different authors.

A difficulty with the analysis has been the very large amount of computation that must be done to accurately simulate the optical response of a grating by RCWA. In particular, the reflected TM light calculation converges very slowly. Most solutions have been to build large libraries of response curves offline and search the library for a best match at the time of measurement. The present invention will allow for separation of the TE and TM components. A library can be searched, matching both TE and TM components for a rough estimation of the grating structure and then relatively fast, real time iteration on normal incidence TE light can be used to refine the measurement.

Description of Figures

Figure 1 depicts the light path and sample as in a normal measurement. Unpolarized light from broadband source **1** is directed to and reflected from sample **7**, **8**, passed through analyzer **11** and detected by spectrograph **13**.

Figure 2 depicts an unpolarized beam directed toward a diffracting grating structure **19** with roughly equal electric field components perpendicular **20** (sometimes called TM) and parallel **21** (sometimes called TE) to the lines of the grating. The beam is reflected from the grating with TE and TM electric field amplitudes modified by the grating structure.

Figures

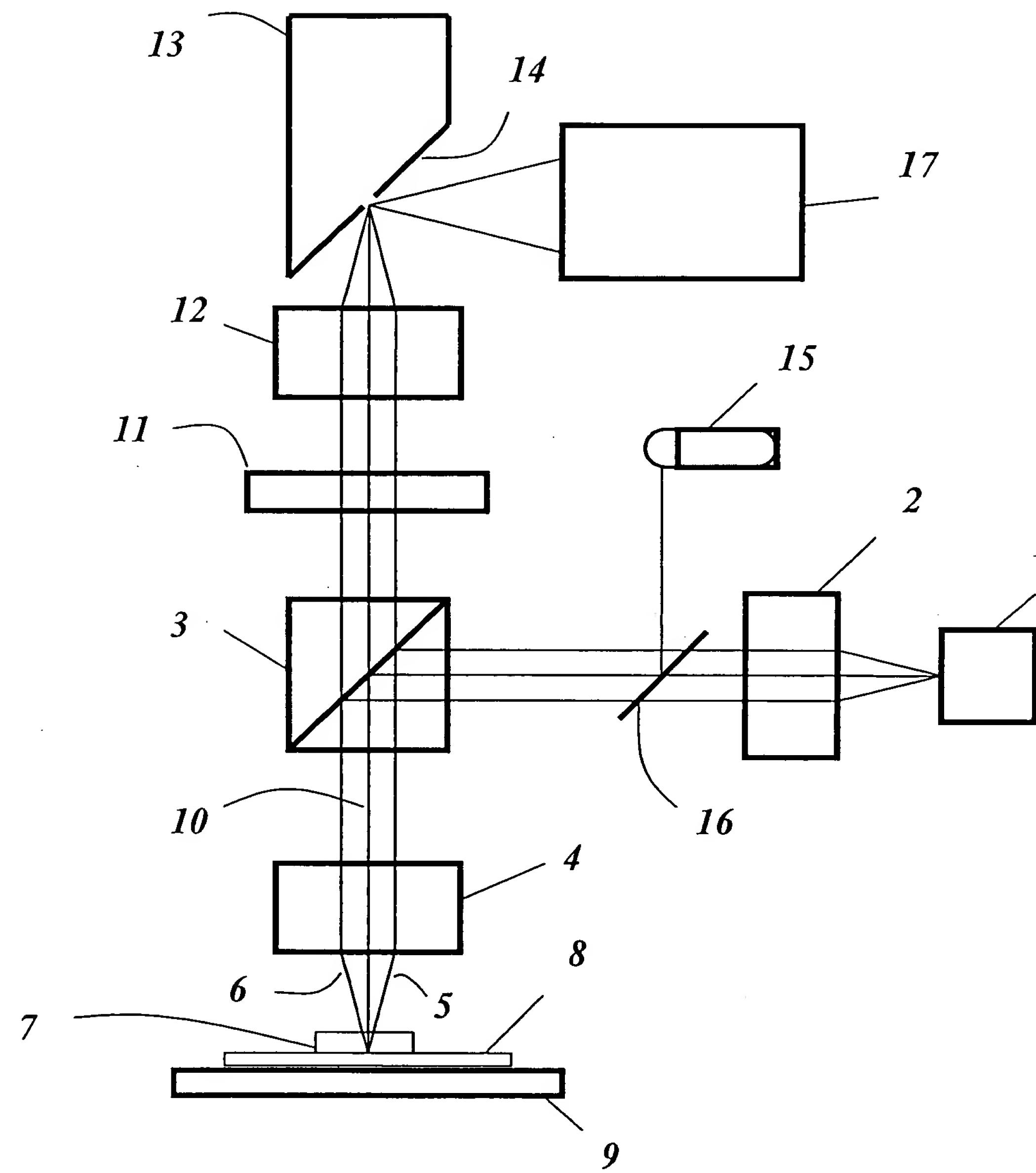

Figure 1

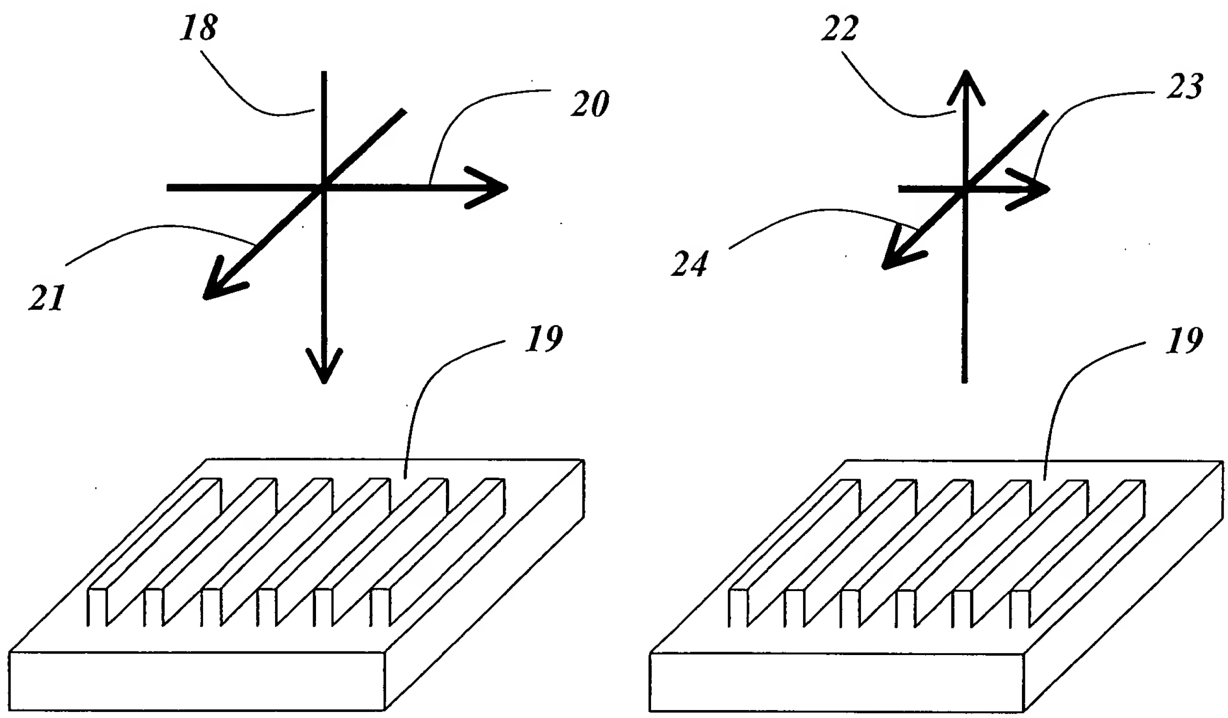

Figure 2

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(408) 453-9200

September 1, 2000

Nanometrics Incorporated
Attn: Legal Department
310 Deguigne Drive
Sunnyvale, CA 94086-3906

Invoice #: 336622
David T. Millers
Client #: 5976
Matter #: M-9455 US

ITEMIZED SERVICES BILL

REGARDING
Normal Incidence Spectroscopic Reflectometer With Analyzer For The Measurement Of Diffracting

Date	Atty	Description	Hours
08/23/00	MJH-2	Analyze disclosure; Phone conference with inventor; Prepare figures and draft patent application	
08/24/00	MJH-2	Draft patent application including preparation of drawings and detailed description	
08/25/00	MJH-2	Draft detailed description and background section	
08/28/00	MJH-2	Draft claims, background section, summary and abstract; Finalize draft and send to Mr. Holden for comments	

Timekeeper	Rate	Hour	Value
Michael J. Halbert			
Total Fees			

Total Fees

DISBURSEMENT SUMMARY

Patents

Total

Total Disbursements

EXHIBIT B

SKJERVEN
MORRILL
MACPHERSON
FRANKLIN
& FRIEL LLP

August 28, 2000

VIA FACSIMILE

Matt Holden
Nanometrics Incorporated
310 Deguigne Drive
Sunnyvale, California 94086-3906

Re: Proposed U.S. Patent Application entitled "Normal Incidence Spectroscopic Reflectometer With Analyzer For The Measurement Of Diffracting Structures"
Inventor: Mattew Holden
Our Reference: M-9455 US

Dear Matt:

The specification for the proposed above-identified patent application has been e-mailed to you for your review and attached herewith are the drawings.

Please review this draft for technical accuracy and completeness of disclosure. We must completely, clearly and accurately describe the invention so as you review this application, please feel free to revise and supplement the description. If there are portions of this draft that are incorrect, please note them. Please also note any blank lines and/or questions located throughout the specification, which must be filled in or answered by you.

It is particularly important that at the time of filing we completely and accurately describe your invention in the application, since we cannot later add new matter to clarify or further describe the invention without running the risk of having to file another application which would lose the benefit of the original filing date for the new matter.

The patent application must:

(1) contain a written description of your invention and the manner and process of making and using it;

(2) describe your invention in sufficient detail to enable one skilled in the art to make and use your invention; and

(3) disclose the best mode contemplated by you of carrying out your invention.

Specifically, if you plan to modify, improve or add features to the invention which are not disclosed in the draft application, these modifications, improvements and features also need to be disclosed in the application as filed. You should also immediately notify us of your planned date for making your invention public (e.g., using your invention publicly in a product,

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San Francisco, CA • Austin, TX • Newport Beach, CA

EXHIBIT C

to be disclosed in the application as filed. You should also immediately notify us of your planned date for making your invention public (e.g., using your invention publicly in a product, offering for sale a product made using or incorporating your invention, publishing a description of your invention, or providing samples of a product incorporating or made using your invention to a third party).

Additionally, we must disclose to the United States Patent and Trademark Office all information known by you to be material to the patentability of your invention. Such information is generally any prior art, any existing patents or patent applications relating to or similar to your invention, and any publication, sale, public use, offer to sell, public knowledge, or invention by others of your invention. If you are or become aware of such information, please provide the information to us.

Finally, if you plan to file this application in foreign countries, please note that some countries do not grant priority based on the filing date of a U.S. patent application. If you do not know whether one or more countries in which you intend to file the application grant such priority, please contact us immediately.

Please provide your comments on this application as soon as possible.

Sincerely,

Michael J. Halbert

MJH:lmc
Enclosure

668118

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October 1, 2000

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Invoice #: 340476
David T. Millers
Client #: 5976
Matter #: M-9455 US

ITEMIZED SERVICES BILL

REGARDING Apparatus And Method For The Measurement Of Diffracting Structures

Date	Atty	Description	Hours
09/15/00	MJH-2	Phone conference with Mr. McGahan and Mr. Holden regarding disclosures; Analyze disclosures and prepare patent application	
09/16/00	MJH-2	Analyze disclosure; Draft patent application including new figures and detailed description	
09/17/00	MJH-2	Analyze disclosure; Draft patent application including detailed description, background section and abstract; Draft and finalize letter to DE, UK and JP foreign associates regarding novelty requirement	
09/18/00	MJH-2	Draft patent application including claims and specification; Fax draft claims to inventor	
09/20/00	MJH-2	Review inventor comments; Revise patent application accordingly; Letter to clinet enclosing draft patent application	
09/21/00	MJH-2	Revise patent application according to inventor comments; Forward draft to inventor	
09/22/00	MJH-2	Revise patent application according to inventor comments; Finalize draft and forward to client	
09/25/00	MJH-2	Phone conference with Mr. Holden and Mr. Flynn regarding finalizing patent application; Finalize and file patent application	

EXHIBIT D

Michael Halbert

From: Matt Holden [mholden@nanometrics.com]
Sent: Wednesday, September 20, 2000 1:05 PM
To: Michael Halbert

M-9455 APP -1.doc ATT27136.txt

Hi Mike, these are my revisions to the application as of now.

Talk to you later.

EXHIBIT E

EXPRESS MAIL LABEL NO:

APPARATUS AND PROCEDURE FOR THE MEASUREMENT OF DIFFRACTING STRUCTURES

Matt's Comments 9-20-00

James Matthew Holden
5088 Golden Drive
San Jose, California 95129
William McGahan

[Note to the Inventor: Please provide current addresses, citizenship and correct full names]

FIELD OF THE INVENTION

This invention relates in general to metrology devices and in particular to metrology devices that may be used to measure diffracting structures.

BACKGROUND

It is desirable to measure circuit structures and other types of structures, e.g., resist structures, during the production of integrated circuits. Optical metrology tools are particularly well suited for measuring microelectronic structures because they are nondestructive, accurate, repeatable, fast, and inexpensive. Often different metrology tools are required to measure different structures or parameters on a wafer. For example, certain structures on a wafer act as diffraction gratings, which conventionally require a different metrology tool, **e. g. critical dimension-scanning electron microscopy (CD-SEM),** than is used to measure planar thin films. ~~, which produce relatively little diffraction.~~

One tool that is sometimes used to measure diffracting structures is a scatterometer. Scatterometry is an angle-resolved measurement and characterization of light scattered from a structure. Scatterometry is discussed in detail in U.S. Serial No. 09/036,557, filed March 6, 1998, which is assigned to KLA-Tencor Corporation, which has an International Publication No. WO 99/45340, dated September 10, 1999, and which is incorporated herein by reference.

U.S. Serial No. 09/036,557 discloses the use of a spectroscopic ellipsometer to measure the diffracting structure. The incident light of the spectroscopic ellipsometer is polarized to provide a beam in the TE mode (S-polarized) when the incidence plane of the beam is

Fig. 1 is a schematic diagram of a normal incidence ellipsometer 100 with a rotatable analyzer/polarizer **(RAP)** 122 and that may be used to measure diffracting structures, in accordance with an embodiment of the present invention. The use of the rotatable analyzer/polarizer 122, advantageously, permits measurement of diffracting structures with a reduced number of parts. Moreover, normal incidence ellipsometer 100 may be used as a reflectometer to measure non-diffracting structures. Thus, normal incidence ellipsometer 100 advantageously need not be a dedicated metrology tool that is used to measure only diffraction gratings, but may be used for other reflectometer-type applications as well.

Normal incidence ellipsometer 100 includes a broadband light source 102, e.g., a UV-visible light source, that produces unpolarized light, which is collected and collimated by lens 104. **[Note to the Inventor: particular wavelengths? We are using 200-800nm]** Beam splitter 106 directs a portion of the collimated, broadband, unpolarized light beam toward the sample that is held on a movable sample stage 118. **This beam is linearly polarized by the rotatable analyzer/polarizer (RAP) 122.** The sample may be, e.g., a diffraction grating structure 114 on a patterned silicon wafer 116. It should be understood, of course, that grating structure 114 is typically very small and that its size shown in Fig. 1 is exaggerated for the sake of clarity.

The light reflected by beam splitter 106 toward the sample passes through the rotatable analyzer/polarizer ("RAP") 122. The rotation of RAP 122 is controlled by a computer 136 in a manner known to those skilled in the art. In another embodiment, RAP 122 is stationary while computer 136 rotates sample stage 118 so that the grating structure 114 is rotated relative to RAP 122.

The RAP 122 passes only the electric field component of the light that is coincident with the polarization axis of the RAP 122 and thus controls the orientation of the light that is incident on the sample. The RAP 122 may be, e.g., ~~a Glen Taylor Air-Spaced Polarizer, a Dichnich Sheet Polarizer or any other appropriate analyzer~~. **A Glan-Taylor air-spaced polarizer, a dichroic Poloroid sheet, or any other appropriate linearly polarizing device.** The light from RAP 122 is focused by objective 108 so that the light is normally incident on grating structure 114. While marginal rays 110 and 112 are at small angles from the normal ray 120 on the sample, the angles are too small to see any polarization effects that occur in conventional ellipsometers.